NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550 FINAL EXAM 6/98 Prof. Powers

- This exam is open book and notes.
- There are four problems; each is equally weighted.
- Partial credit will be given; be sure to do some work on each problem.
- Be sure to include units in your answers.
- Please circle or underline your answers.
- Show *ALL* work.
- Write only your name on this sheet.
- Exams and course grades *should* be available outside the Optical Electronics Laboratory (Bu 224) on **Friday afternoon, 19 June**.
- The originals or copies of this exam and/or its solutions are not to be given or lent to anyone else.

Course grade: _____

1		3	
2		4	
TOTAL			

Name: _____

FIBER SPECIFICATIONS

	Fiber #1	Fiber #2	Fiber #3	Fiber #4
Size	50/125	62.5/125	10/125	100/140
n_1	1.45	1.46	1.45	1.46
g	1.88	∞	∞	1.85
NA	0.22 (at $r = 0$)	0.20	0.11	0.18 (at $r = 0$)
α @ 850 nm	2.0 dB/km	1.0 dB/km	1.2 dB/km	5.0 dB/km
α @ 1300 nm	1.0 dB/km	0.8 dB/km	0.7 dB/km	2.0 dB/km
α @ 1550 nm	0.6 dB/km	0.4 dB/km	0.4 dB/km	0.8 dB/km

SOURCE SPECIFICATIONS

	Laser #1	Laser #2	LED #3	Laser #4
Wavelength	850 nm	1300 nm	850 nm	1550 nm
$\Delta\lambda$	0.5 nm	1.0 nm	25 nm	1.1 nm
Power at pigtail end	0.70 mW	0.8 mW	60 μW	2.0 dBm
Pigtail size	62.5/125 μm	10/125 μm	200/300 μm	10/125 μm
Pigtail NA	0.20	0.12	0.25	0.11
Pigtail type	Step index	Step index	Step index	Step index

DETECTOR SPECIFICATIONS

	Detector #1	Detector #2	Detector #3
Material	Silicon	Germanium	InGaAs
Responsivity A/W @ $M = 1$	0.8 @ 850 nm	0.2 @ 1300 nm 0.3 @ 1550 nm	0.3 @ 1300 nm 0.45 @ 1550 nm
C_d	3 pF	1 pF	2 pF
Excess noise factor	$M^{0.3}$	M^{1}	$M^{0.6}$
Bulk dark current	0.10 pA	1 μA	0.1 μA
Surface dark current	0	1 nA	0

IMPORTANT: Specifications of numbered components are given in the tables.

1. A fiber link is to use Fiber #3 with Laser #4. The receiver requires a power of -22 dBm to achieve the desired BER at 1 Gb/s. The coding is NRZ.

   (a) Find the attenuation-limited transmision length.

   (b) Find the dispersion-limited transmission length.

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2. Consider a connection with light passing from fiber #2 into fiber #4. Calculate the estimated total connector loss (in dB), assuming that the lateral misalignment is 10% of the core diameter of fiber #2, that the longitudinal separation of the ends is 40% of the core diameter of fiber #2 and that the angular alignment is perfect. There is an air gap between the fiber ends.

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3. We have a long link with a series of fiber amplifiers that are evenly spaced. The signal power out of the amplifiers is kept constant at 5 mW, which is also the value of the input power to the link. The following amplifier parameters apply: $LG_0 = 3.2$, $G_0 = 30$ dB, $n_{\rm sp} = 1.4$, $\lambda = 1550$ nm, and $\Delta\lambda = 20$ nm. The linewidth of the optical filter following each amplifier is $\Delta\lambda = 1.22$ nm. The bit rate of the link is 10 Gb/s.

   (a) Calculate $R_{\rm ASE}$ at the output of the 100-th amplifier.

   (b) Calculate the BER that could be supported at the output of the 100-th amplifier.

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4. Consider the bidirectional singlemode fiber link shown in Fig. 1 below. The splices (indicated by the "x" in figure) have a loss of 0.5 dB. The excess loss of the 2x2 couplers is one dB (and does *not* include the splice losses). Laser #2 is the source used in transmitter #1. The fiber lengths in each leg are equal.

   The receiver in RCVR #1 has a sensitivity (at a BER of 10^{-9}) given by

   $$P_R[dBm] = 11\log\left(B'_R[\text{Mb/s}]\right) - 58 \tag{1}$$

   where P_R is in units of dBm and B'_R has units of Mb/s.

   Based on the power budget, calculate the data rate that can supported by this link from Xmtr #1 to Rcvr #1. (You may ignore the fiber losses in the device pigtails.)

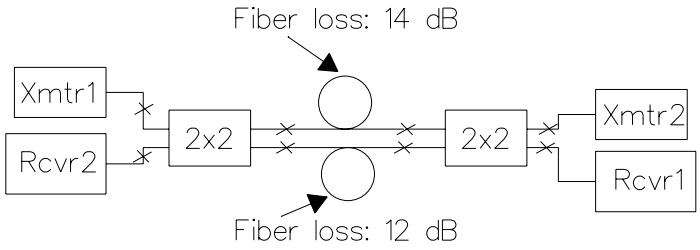

Figure 1: Fiber bidirectional link for Problem 4.